View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Journal of Economics Library

Journal of Economics Library
www.kspjournals.org
Volume 5 March 2018 Issue 1

Climate change and profit efficiency in Punjab, Pakistan: Evidence from household-level panel data

By Khush Bukhat ZAHID [a†] & Munir AHMED [b]

Abstract. This study seeks to examine, both theoretically and empirically, the impact of climate change on farm Profit efficiency in Rural Punjab Pakistan. Current study explores the climate change impact by using Stochastic Profit Frontier Model at farm level with panel data. The outcomes of this study are indicative of a strong impact of climate change on the agriculture of Punjab, Pakistan. Increase in long run normal precipitation and temperature have significant effect on farm profit that fluctuates in direction as well as magnitude across quarters. The incidence of weather shocks and socioeconomic characteristics of the farming households are important factors of profit efficiency at farm level. The quasi fixed inputs are positively and significantly related to farm profits while input prices contribute negatively to farm profitability. The average profit efficiency score turned out to be 0.72, suggesting that the average farm, by improving their efficiency can increase the profit up to 28 percent. The findings of present study are evocative of huge impact of climate change on the rain-fed areas of Punjab since these are water scarce areas depending on rain fall for cropping. Arguably, it is vital for the better performance of the agriculture sector to combat the impact of climate change more effectively through implementation of adaptation strategies.
Keywords. Agriculture, Farm production, Climate change, Profit efficiency, Stochastic profit frontier model and farm level panel data.
JEL. C23, D01,Q12.

1. Introduction

There is consensus among climate scientists that damages to agriculture from climate change will be disproportionately concentrated in developing countries whose economies are largely farm based. The effects on industrial economies will understandably be modest if long term aggregate global effects are taken into account. It is projected that in another twenty or thirty years global warming will actually benefit farm production in developed countries of higher latitude where temperatures and precipitations have not reached the critically damaging level that lower latitude countries have already attained. Scientists agree that there is no doubt that developing countries are going to feel the impact of climate change on their agriculture much sooner and more severely since they lack the technological knowhow and capacity to adapt. This consensus serves a timely warning to agronomists, breeders and economic managers of the developing world, in particular of South Asia, where local agriculture's proneness to respond to climate change in the shape of falling output, floods and droughts has been evident for some years. It is time for the economic managers in Pakistan to engage them in

[a†] Kashmir Institute of Economics University of AJK muzaffarabad, Pakistan.
☎. + 05822442573
✉. khushbukhatphd2009@gmail.com
[b] Pakistan Instiitute of Development Economics, Islamabad, Pakistan.
☎. +92519248095
✉. Munir@pide.org.pk

preparing their farming communities for the challenges posted by climate change. This study attempts to add its bit to emphasizing the urgency of these forecasts.

Climate change is one of the biggest threats the earth faces in the form of turbulent weather. The addition of greenhouse gases in the environment is causing global warming which has emerged as an important issue in the recent past for the changes it is bringing about in climate patterns and its potential future impact on the wellbeing of the earth's inhabitants. According to the Intergovernmental Panel on Climate Change (IPCC), "…*climate change refers to a change in the state of the climate that can be identified by changes in the mean or variability of its properties and that persists for extended periods, typically decades or longer*" (Lee, Nadolnyak & Hartarska 2012:1). The increase in volume of "greenhouse gases[i]" raises the temperature of the earth and changesthe precipitation pattern. The rise in earth's temperature is causing frequent occurrence of extreme weather events having devastating effects on crops' performance as well as livelihoods and food security of the people, especially the vulnerable among them (UN, 2015).

Economies of developing countries largely depend on the agriculture sector (Finger & Schmidt 2007; Nelson, *et al*., 2009; Crosson, 1997 and Schipper, 2004). Furthermore, developing countries lack the capacity to adapt to climate changes (Eriksen *et al.,* 2008). Therefore, climate change can wreak havoc in these countries. Though there are several other factors which contribute to agricultural productivity such as technological advancements, policy environment and optimal utilization of physical inputs (Cabas *et al.,* 2010), but these factors cannot contribute effectively to the performance of agriculture unless the climatic and weather[ii] conditions are favorable for plant growth and animal rearing. Even the day to day variations in weather conditions constrain the agricultural practices resulting in low productivity (White, 1985). Any abnormal variation in the climate or weather influences the factors of production resulting in wide range of losses in proportion to the severity of climatic shocks. Various studies have empirically estimated the impact of climate change on agriculture and shown diverse results, the empirical literature in general concludes that agricultural production is affected both negatively and positively.[iii]In short these impacts change over time which depends on the magnitude and rate of the climate change (Steffen *et al.,* 2004; O'Brien & Leichenko, 2003 and Leichenko & O'Brien, 2006).

Pakistan is not an exception and is the most vulnerable[iv] country in the South Asian region because of its overwhelming dependence on agriculture which is sustained by the Indus Basin River System. The farm lands of Pakistan are mostly categorized as arid to semiarid, where rainfall is not enough to grow agricultural crops adequately (Waraich & Mohsin, 2005). About 11 percent of the area receives 250-500 mm annual rainfall, one half of the area has an annual rainfall of 150-250 mm and about one-third receives less than 150 mm annually. The country on the whole is classified as arid (Iqbal *et al.,* 2008) with the added susceptibility of the sector to the climatic condition. The Task Force on Climate Change (TFCC) indicated that the temperature increases in Pakistan are predicted to be higher than the worldwide average resulting in significant reduction in agricultural production (TFCC, 2010).

Climatic variables such as precipitation, temperature, humidity and others affect production through different stages of plant growth. Climate change affects the timing and application of inputs resulting in inefficiency and low yields. An unfavorable climate influences productivity of factor inputs causing production losses and affecting profit efficiency. The present study uses stochastic frontier approach as a primary method of analysis. Farm specific inputs and climate are explicitly incorporated in the model. The study also investigates the effects of various farmer characteristics, such as age, education, tenurial status and farm size on the farmer's efficiency. *'Inefficiency Effect Model'* includes the function in which technical efficiency is made explicitly dependent on farm specific characteristics in line with Battese & Coelli (1995).

Literature, evaluating the impact of changing climate on farm profit efficiency is also quite scarce. Recently, Pereda & Alves (2012) analysed the impact of climate change on farm profit of majorcrops in Brazil. The study at hands differs from Pereda & Alves (2012) both in nature and scope. Firstly, this workundertake analysis at farm level using all crop data and all seasons for the whole agriculture year. Secondly, it estimate the model in single step procedure Battese & Coelli (1995) and Battese *et al.,* (1996) criticized the two-step modeling approach on the ground that it violated one of the most vital assumptions of stochastic frontier model i.e. 'identically independently distributed technical inefficiency effects'.as contrary to Peredawhich uses only census data at district level and divide climate data into two seasons data to represent climate.Therefore the present study measures the impact of climate change more precisely at finer intra-temporal and spatial scale to better capture the impact of climate change.while others such as Rahman (2003) and Wadud (2003) analyzed Bangladeshi farmers' profit efficiency of rice by using restricted normalized profit frontier approach. Crop inputs and socio-economic characteristics of the farmers that were used to explain farm profit and inefficiency but did not consider climatic variables in their approach to explain farm efficiency.Similarly, Rios & Shively (2005), Nganga, *et al.,* (2010) and in Pakistan Javed *et al.,* (2009) Javed *et al.,* (2011) also measures efficiency of crops but without considering climate variables.

Empirical analysis would involve the study of impact of climatic factors along with socio-economic variables on farmers' production efficiency. The available studies relating the subject have used national level data or district level data for the analysis due to non-availability of household level data such as Pereda & Alves (2012).The study in hand would thus be a first attempt to study the impact of climate change at the household level in Pakistan. It uses farm survey data collected by Punjab Economic Research Institute (PERI) and matches this data with climatic data of respective households based on village level latitude and longitude.The existing studies on efficiency of Pakistan's agriculture do not give a clear picture of farmers' profit efficiency because they use farm level data on a single crop, mostly wheat and rice, and few categories of inputs while climate change is not factored in the analysis (Battese *et al.,* 1993 and Ali, Parikh & Shah 1996). The present study extends this analysis to all the crops together with all measureable inputs and includes climatic variables. Its outcomes are therefore more reliable.

Available efficiency studies have mostly been focusing on farm and farm operators' attributes to evaluate the sources of measured efficiencies. Against this backdrop, the present study, assesses the impact of weather shocks (climatic deviation) in addition to these variables, extends the previous work in coverage and scope. Moreover the analysis is extended by analyzing the effect of climate change on profit efficiency. This area had previously been ignored by researchers, who focused merely on farm productivity. Indeed, profit efficiency is a broader concept since it incorporates both input and output oriented efficiencies.

The remaining part of the paper is structured as follows: Section 2 discussed material and methods Section 3 discussed results and discussion, concludes the study and suggests recommendations.

2. Material and Methods

2.1. Stochastic Frontier Analysis

The production frontier applying estimated stochastic frontier method is more appropriate way to measure production efficiencies while using unit level datasets such as the household farm survey (Hughes *et al.,* 2011).The stochastic frontier model also allows producers specific random shocks (Thiam & Bravo-Ureta 2001). The traditional deterministic approaches can lead to overestimation of technical inefficiency because of not taking account of noise. The stochastic frontier approach uses a 'composite error term' having two components. One is technical inefficiency that is 'farm deviations from the production frontier,' and the other is statistical noise capturing the effect of random shocks on each producer characterized by the environment under which he/she operates (Coelli, 1995). Additionally, this method also allows the statistical test of hypotheses' in respect of the production structure and the degree of inefficiency.

2.2. Study Area and Data

The area of this study is Punjab Province of Pakistan while data is taken from different agro ecological zones i.e barani, partial barani and irrigated zone following to the reason that their specific agronomic characteristics can provide important insights for our research questions. In crops wheat, rice, maize, sugarcane, cotton and others[v] are taken for simplification because these crops cover the major area of Punjab under cultivation. The farm level panel data collected by Punjab Economic Research Institute (PERI) from 537 farm families in the study area is available for the agricultural years 2005-06, 2006-07 and 2007-2008. The sample included fair representation of small, medium and large size farm households[vi]. Profit (Gross Margin) serves as dependent variable which is computed as difference of revenues from crop outputs and variable costs involved. Profit (Gross Margin) is calculated as total revenue from crop production minus the variable cost. Total revenue includes revenue obtained from selling of crops and by products. The variable cost includes labor, fertilizer, seed, irrigation, pesticides and weedicides and farm yard manure, involved in production of crops. In profit frontier we used six quasi-fixed variables: four inputs--land, seed, permanent labor and capital; and two climatic variable—temperature and precipitation measured as 20 years moving average; and three variable inputs (labor, irrigation, and material inputs). The prices of three variable inputs are wage rate (labor), per irrigation price, and price index of material inputs[vii] (fertilizer, charges per chemical application (weedicide and pesticide), price of farm yard manure (FYM) per cartload).

For quasi-fixed inputs, land is total cultivated area in acres while seed index used is same as constructed above, labor is permanent hired and family labor involved in farm work measured in male adult equivalent MAE. Labor is an important factor in farm productivity. Those farmers who don't have their own labor they hired them who are paid in kind and/or cash. Male adult equivalent (MAE) is define as a person working 100 percent for 300 days per annum or 8 hours daily for 25 days per month was consider as one male adult equivalent. Capital is the total of the present value of farm implements, tractors and tubewells owned by the farmers. The farm implements include cultivators, trolley, thresher, reaper, sprayers, and other farm implements and climatic variables are 20 year moving average of monthly precipitation and temperature. Descriptive statistics is reported as Table-1 in Appendix.

According to Battese (1997), it is also necessary to incorporate dummies for variables having zero values in the data to describe various production systems for farmers who use definite inputs as compared to those who do not. Using Cobb-Douglas or Translog functional forms in absence of dummies could lead to biased parameter estimates. This procedure applied by many including Battese & Broca (1997), Ahmad (2003), Ahmad *et al.,* (2002) and Nasim, Dinar & Helfand (2014). All the inputs in the sample contain at least some zero values, to account for zero values in the Cobb Douglas function we follow Battese & Broca (1997) adding a dummy variable D_k in the production function and transforming $\ln x_k$ to $\ln x_k^*$ where k is the input for which this dummy specifies.

$$D_k = \begin{Bmatrix} 0 & if x_k = 0 \\ 1 & if x_k > 0 \end{Bmatrix} \text{and } x_k^* = ArgMax(x_k, 1 - D_k) \quad (1)$$

The above transformation implies that when the inputs x_k is applied then $x_k^* = x_k$ but when x_k is not applied $x_k^* = 1$ the inclusion of dummies signifies that the intercept term differs between farmers that apply the input and farmers that do not apply the input.

2.3. Stochastic Profit Frontier Model

Specification of profit function is parameterized Cobb-Douglas log function[viii] which is used as an empirical approach. It is assumed that the farmers are producing single or multiple crops by using the fixed inputs including capital, labor, land and environmental factors—temperature and precipitation normal, and the profit function is specified as a restricted profit function. This implies that these inputs are specified as being fixed in the short run. Moreover, in order to impose the property a function being homogeneous in prices, that function is normalized with respect to output price. Hence, the stochastic restricted normalized profit function is specified and estimated using capital, land, seed and labor input factors in the presence of variable inputs prices under different climatic conditions as follows.

$$\ln\left(\frac{\pi_{it}}{p_{it}}\right) = \beta_0 + \beta_1 \mathrm{lnCA_{it}} + \beta_2 \mathrm{lnPFL_{it}} + \beta_3 \mathrm{lnFI_{it}} + \beta_4 \mathrm{lnseed_{it}} + \beta_5\ ln\frac{mat_{\,it}}{p_{it}} + \beta_6 ln\frac{\mathrm{wag_{\,it}}}{p_{it}} + \beta_7 ln\frac{\mathrm{Irri_{\,it}}}{p_{it}} + \beta_8 \mathrm{dcw}_i + \beta_9 \mathrm{drw}_i + \beta_{10} \mathrm{dmw}_i + \beta_{11} \mathrm{dt}_2 + \beta_{12} \mathrm{dt}_3 + \beta_{13} \mathrm{P_{1it}} + \beta_{14} \mathrm{P_{2it}} + \beta_{15} \mathrm{P_{3it}} + \beta_{16} \mathrm{P_{4it}} + \beta_{17} \mathrm{T_{1it}} + \beta_{18} \mathrm{T_{2it}} + \beta_{19} \mathrm{T_{3it}} + \beta_{20} \mathrm{T_{4it}} + v_{it} - u_{it} \quad (2)$$

Where

$$\left(\frac{\pi_{it}}{P_{it}}\right) = [(\textstyle\sum_{i=1}^{n} P_{it}\, Y_{it} - \sum_{i=1}^{n} W_{it}\, X_{it})/p_{it})] \quad (3)$$

$\frac{\pi}{p}$ is restricted normalized profit computed for i[th]farm defined as farm revenue less variable costs divided by output price—wheat price which is major crop produced by all the sample farmers.

The coefficients are estimated by MLE using R-Frontier software.

Following Battese & Coelli (1993) the technical inefficiency effects of u_{it} gain in the above equation are specified as.

$$u_{it} = d_0 + d_1 \mathrm{age}_{it} + d_2 \mathrm{edu_{it}} + d_3 \mathrm{farmsize_{it}} + d_4 \mathrm{dtenant_{it}} + d_5 \mathrm{DVp}_{1it} + d_6 \mathrm{DVp}_{2it} + d_7 \mathrm{DVp}_{3it} + d_8 \mathrm{DVp}_{4it} + d_9 \mathrm{DVt}_{1it} + d_{10} \mathrm{DVt}_{2it} + d_{11} \mathrm{DVt}_{3it} + d_{12} \mathrm{DVt}_{\,4it} \quad (4)$$

We finally estimate the profit efficiency of each producer based on the distributional assumption discussed below (Coelli, 1993).

3.Findings

3.1. Stochastic Profit Frontier Empirical Results

Equation 2 and 4 was estimated using R-Frontier Package. This statistical package provides maximum-likelihood estimates (MLE). The results of the profit frontier function incorporating inefficiency effects in the model are reported in Table 2.

Table 2: *The Maximum Likelihood Estimates for Cobb-Douglas Profit Frontier*

	Variables	Parameters	Coefficients	Std. Error
	Profit Function			
	Constant	$\beta_\circ$	0.69	1.05
Log of Cultivated Area	lnCA	β_1	0.51***	0.03
Log of permanent family labour	LnPFL	β_2	0.00	0.03
Log of present value of farm implement	LnFI	β_3	0.02***	0.01
Log of seed value index	Lnseed	β_4	0.31***	0.02
Log of material price index	Lnmat	β_5	-0.08***	0.01
Log of wage rate of hired labour	Lnwag	β_6	-0.04***	0.01
Log of irrigation rate	Lnirri	β_7	-0.05**	0.02
Dummy variable for cotton wheat zone	Dcw	β_8	0.77***	0.07
Dummy variable for rice wheat zone	Drw	β_9	0.97***	0.06
Dummy variable for mixed zone	Dmw	β_{10}	0.65***	0.05
Dummy variable for year 2006-07	dt1	β_{11}	0.20***	0.04
Dummy variable for year 2007-08	dt2	β_{12}	0.66***	0.06
Precipitation normal for April-June	P_1	β_{13}	0.00*	0.00
Precipitation normal for July-Sept	P_2	β_{14}	0.00	0.00
Precipitation normal for Oct-Dec	P_3	β_{15}	-0.01*	0.01
Precipitation normal for Jan-March	P_4	β_{16}	0.04***	0.02
Temperature normal for April-June	T_1	β_{17}	-0.10**	0.05
Temperature normal for July-Sept	T_2	β_{18}	0.03	0.07
Temperature normal for Oct-Dec	T_3	β_{19}	-0.04	0.09
Temperature normal for Jan-March	T_4	β_{20}	0.29***	0.07
	Profit Inefficiency Model			
Age of household head	Constant	$d_\circ$	-2143.20**	880.35
Education of household head	lnCA	d_1	-2.04**	0.82
Total area of farm in acres.	LnPFL	d_2	20.06**	8.27
Dummy variable if the farm is rented in	LnFI	d_3	1.30**	0.53
Deviation of first quarter average rainfall	Lnseed	d_4	126.74**	52.83
Deviation of second quarter average rainfall.	Lnmat	d_5	-3.49**	1.42
Deviation of third quarter average rainfall	Lnwag	d_6	-2.15**	0.93
Deviation of fourth quarter average rainfall	Lnirri	d_7	1.71**	0.69
Deviation of first quarter average temperature.	Dcw	d_8	21.30**	8.70
Deviation of second quarter average temperature	Drw	d_9	-316.19**	128.98
Deviation of third quarter average temperature.	Dmw	d_{10}	-111.46**	45.10
Deviation of fourth quarter average temperature.	dt1	d_{11}	-36.42**	16.39
	dt2	d_{12}	-169.05**	69.19
	P_1			
	P_2	σ^2	579.03**	238.90
	P_3	Γ	0.99***	0.00
	P_4		-1458.531	

Note: ***, **, * indicate significance at 0.01, 0.05 and 0.1 probability levels

The results of tests of hypotheses are reported in Table -3. The first null hypothesis which was tested relates to $H_0: \gamma = 0$ specifying that the inefficiency effects do not exists in the model. The value of key parameter, γ, which is defined as $\frac{\delta_\mu^2}{\delta_u^2+\delta_v^2}$, ranges between 0 and 1; 0 implies no inefficiency, and 1 indicates no random noise[ix]. The null hypothesis was rejected implying that there exists profit inefficiencies at the sampled farms. The magnitude of γ is close to 1 and is significantly different from 0 shows the existence of high level of inefficiencies at the sampled farms. Moreover, the corresponding variance-ratio parameter implies that 99% of the differences between observed and the maximum frontier profits are due to the existing differences in efficiency levels among farmers. The second null hypothesis $H_\circ: \gamma = d_\circ = \ldots d_n = 0$, which specifies that the inefficiency effects are not present in the model, was also rejected at the 5% level of significance. This result confirms the above finding that a significant part of the variability in profits among farms is explained by the existing differences in the level of technical inefficiencies. The third null hypothesis, $H_\circ: d_1 = \ldots\ldots d_n = 0$, was again rejected. This result implies that the variables included in the inefficiency model significantly explain the variation in profit inefficiency. The fourth null hypothesis is $H_\circ: d_5 = \ldots\ldots d_{12} = 0$ which specifies that climatic deviations jointly have no impact on profit inefficiency. This hypothesis was also rejected implying that climatic shocks do explain the variations in farm profit inefficiencies statistically significantly.

Table 3. *Generalized Likelihood-Ratio Tests of Hypothesis for the Profit Frontier Model*

Null Hypothesis	LR	DF	Critical Value X^2	Decision
$H_\circ: \gamma = 0$	164	1	3	Reject $H_\circ$
$H_\circ: \gamma = d_\circ .. = d_n = 0$	291	14	23	Reject $H_\circ$
$H_\circ: d_1 = \ldots \ldots d_n = 0$	137	13	21	Reject $H_\circ$
$H_\circ: d_5 = \ldots \ldots d_{12} = 0$	58	8	14	Reject $H_\circ$

Note: These critical values are taken from Table 1 of Kodde & Palm (1986) at 5% level of significance.

Based on the estimates of the profit frontier function, we computed basic features of the production structure, namely, profit elasticities with respect to changes in variable input cost and fixed factors. The material price index, wage and irrigation rate are significant and carry expected signs that are negative. The incremental contribution of farm capital, land, permanent family labor and seeds contributed positively to farm profit. Results of the model also demonstrate that all estimated coefficients of zone specific dummy variables are statistically significant and carry positive signs indicating higher profitability in irrigated areas relative to the rain-fed zone.

The results of climate variables show that precipitation normal significantly contribute towards farm profit, except that of the October-December which is affected negatively and significant—implying that better precipitation helps crop productivity if the temperature stays at the historical mean. Also increased precipitation results in high humidity that can cause high pests and diseases of crop and ineffectiveness of weed control measures (ICARDA, 2011). The parameter estimates of first and fourth quarter temperature variables are statistically significant at least at the 5 percent level of significance. The rise in temperature normal during April-June contributed negatively and January-March contributed positively towards farm profit while July-September and October –December temperature are insignificant.

3.2.Analysis of the Determinants of Profit Inefficiency

The impact of the socio-economic factors accounting for farm inefficiency is listed in the lower panel of Table -2. The results show that education of head of the household has significant positive impact on profit inefficiency—implying that more educated farmer are less involve in farm production due to off farm jobs and realizes less profit. The farm size also affects inefficiency significantly positively. The impact of farm size on inefficiency is mystifying. The large farm area positively contributed efficiency on the one hand and negatively on the other hand because having larger planting area, enhance the ability of the farmers to apply modern technologies such as tractors and irrigation while other group of researchers is arguing that small farmers are more efficient in managing limited available resources for their survival because of economic pressure. Therefore, farmers with large farm size could be more efficient or less inefficient. The parameter estimate of tenancy variable shows that the tenants are inefficient relative to the owner and owner-cum-tenants.

Variations in temperature and precipitation from their respective long term means have also been used to examine the impacts of climatic shocks. All parameter estimates of climate related shock variables—temperature and precipitation deviations, are significant at least at the 5 percent probability level. The parameter estimates of rainfall deviation variables, April-June (DV_{p1}) and July-Sept (DV_{p2}), carry negative signs implying that excessive rains had potential to reduce farm level technical inefficiency during these periods that mostly covers summer crops. However, our data shows average rainfall deviations for third quarter DV_{p3} and fourth quarters DV_{p4} months (Oct-Dec and Jan-March) are positive. These months cover winter crops season *(rabi)* and the results imply thatpositive rain shocks (positive deviations from the long term trends) would reduce farm efficiency.

All parameter estimates of temperature deviation variables are statistically significant and negatively contribute to inefficiency levels. Our data show that average temperature deviations in fact are negative for DV_{t1}, DV_{t2}, DV_{t3} and DV_{t4} from long term means which imply that the lower temperature from long-term means has reduced the level of technical inefficiency pushing farmers further close the profit frontier. The impact of temperature deviations during the period of October-December (DV_{t3}) was though positive on efficiency and found statistically significant. The deviations of January-February (DV_{t4}) also contributed positively to profit efficiency. (DV_{t3}) and (DV_{t4}) period represents mainly the sowing and vegetative growth stages of winter crops i.e. wheat, peas and gram therefore the negative temperature shocks have potential to reduce farm inefficiency. The mean of the deviations during this period is negative implying negative temperature shocks (cooling up weather compared to historical trends) leading us to conclude that low temperature than the historical mean helps raise farm efficiency. This result is consistent with the findings of Ahmed, *et al.,* (2014).

3.3. Profit Efficiency Distribution

The average profit efficiency scores presented in Table 4 show that average profit efficiency score is 0.72; the average farm could increase profits up to 28 percent by improving their technical efficiency. Results show that there exist a widespread in profit inefficiency ranging from 95 percent to less than 0.02 percent. The observed results are not unexpected; similar results were found by previous empirical studies in Pakistan, e.g. Ali & Flinn (1989) stated mean profit efficiency level of 0.69 (ranging between 13–95%) in Punjab while Ali *et al.,* (1994) reported 0.75 (ranging between 4–90%) in KPK province for rice producers. However, the results shows that a substantial amount of unexploited profit exists in agriculture that can be realized by using even the existing technologies more efficiently in production.

The distribution of profit efficiency of sampled farmers is presented in Table -5 that indicate that the proportion of famers having efficiency score below 0.80 slightly decreased in second year and increases in third year, while the proportion of farmers having efficiency score of above 0.80 have declined. However, the overall trend of profit efficiency measures slightly decreased overtime. And most of the farmers are concentrated in efficiency range of 60 to 90 percent.

Table 4. *Mean of Profit Efficiency Estimates for Each Year*

Year	Efficiency Scores
Year 1	0.77
Year 2	0.65
Year 3	0.74
Mean Profit Efficiency	0.72

Table 5. *Profit Efficiency Estimates Distribution Using CD -SFA Model*

PE Range	Percent of Farms Year 1	Percent of Farms Year 2	Percent of Farms Year 3
<50	2	16	5
50-60	3	10	6
60-70	8	19	10
70-80	34	34	36
80-90	52	20	41
90-100	1	1	2
Total	100	100	100

Source: Author's own calculations

4. Conclusions and Recommendations

The study also estimated the variable profit function applying the SFA incorporating the profit inefficiency model. The results show the existence of wide range profit inefficiencies with an average score of 72 percent—highest efficiency score was 95 percent leaving room for improvement in farm profits by 23 percentage points by using farm resources more efficiently. The results further show that the climatic variables—long-term normal and short term climatic shocks, significantly influence farm profits and efficiencies which have serious implications for the agriculture sector of Pakistan. The results are suggestive of the fact that fighting climate change through promotion of mitigation and adaptation strategies and enhancing farm level production efficiencies with provision of formal education, facilitating consolidation of lands, and securing tenancy, shall be the key elements to improve the performance of the agriculture sector as well as the farm household food security

The major objectives of the study were to quantify the impact of changes in climate on the performance of farm. To this end the study confirms the premises that climate change affects agricultural profitability considerably.

Therefore, there is a need to take steps:

- to handle the adverse effects of climate change on crop production, efficiency and food security through devising and promoting mitigation and adaptation strategies;
- to enhance off-farm employment and investment opportunities in order to facilitate the exit of extremely inefficient farmers.
- to improve the educational system in rural areas making it more accessible to the general public—particularly for those living in far flung areas;
- to re-orient the agricultural extension system to meet the challenges of climate change, since extension agents are the one who could better train the farming communities to improve their management skills under the changing scenarios of the environment; and
- to modernize the weather information and forecasting system that could cope with the information gap spurred by the vagaries of nature.

In addition to above, it is generally believed that the changing climatic conditions would further worsen the shortages of irrigation water in the country. The crops are already being grown under water stress and rise in temperature would result in enhance water requirements by the plants. Therefore, it is crucial to enhance water storage capacity in the country in order to ensure sustainability in agricultural production system. Therefore, there is need to increase input and output market efficiencies through better infrastructure and farmers friendly policies that in turn would reduce the cost of production and make the sector more competitive.

Notes

[i]Pakistan's total GHGs emission in the year 2008 were 309 million tons (mt) comprising of CO2 (54%), methane (36%), nitrous oxide (9%) and one percent of other gases (TFCC, 2010) which is due to emission of methane from rice paddies (Cicerone & Shetter, 1981) carbon dioxide and greenhouse gases (GHG) from industrial production and burning of crop residues (Rehan & Nehdi 2005) and atmospheric brown clouds (ABC) from sea salt and mineral dust (Ramanathan et al., 2007).

[ii] "The distinction between weather and climate is a measure of time. Weather is conditions of the atmosphere prevailing over a short period of time while climate is over a relatively long periods of time" (NASA).

[iii]The studies like Adams et al., 1988; Cline 1996; Parry, et al., 2004; Lobell, et al., 2007; and Cabas et al., 2010 among others found negative relation, while some others found positive association between increase in temperature and agricultural production such as Gbetibouo & Hassan 2005.

[iv]Maplecroft Climate Change Vulnerability Index (CCVI) ranked Pakistan 24th in the list of countries most vulnerable to climate change.

[v] Include Pulses, Vegetable, Orchards, Groundnut, Gram, Fodder and Oil seed.

[vi] 'Small-A defined as farms with farm size less than 5 acres; Small-B, farms with size between 5 to 12.5 acres; Medium, farms with size between 12.5 and 25 acres; and Large, farms with size 25 acres or more.

[vii]FPI is preferred indexing procedure to use. The difficulty with the LPI and PPI number formulas is that they are consider similar but overall they will give different results. Diewert (1993) and Walsh (1901) also proposed FPI index in one of his numerical examples while pointing the differences between the Laspeyres and Paasche indices.

[viii]We also estimated the model with one of the flexible functional form, such as the translog, but in our case Cobb-Douglas performed better in terms of economically reasonable parameter estimates.

[ix] "If γ is not significantly different from 0, the variance of the inefficiency effects is 0 and the model reduces to a mean response function in which the inefficiency variables enter directly (Battese & Coelli, 1995)".

Appendix

A1. *Definition of Variables and their Descriptive Statistic*

Variables	Definition	The Stats are in Actual (non-log)			
Profit Frontier		mean	S.D	min	max
$\frac{\pi}{p}$	natural log of restricted normalized profit	196755	290982	975	5024080
Lnmat	natural log of material price index normalized by output price.	1.14	0.37	0.00	4.88
Lnwag	natural log of wage rate of hired labor normalized by output price.	81	131	0	1,250
Lnirri	Natural log of price of irrigation normalized by output price	547	2352.68	0	26920
lnCA	natural log of area under cultivation in acres	9.28	12.73	1.00	174.00
lnPFL	natural log of permanent family labor in MAE	3.67	1.75	1.25	12.5
lnFI	natural log of present value of farm implement	117,910	170,593	0	1,223,980
Lnseed	natural log of seed index value	108.34	238.60	1.65	6983.03
	Cropping zones Dummies				
Dcw	dummy variable assuming value of One if farm is located at cotton wheat zone , otherwise Zero;	0.32	0.47	0	1
Drw	dummy variable assuming value of One if farm is located at rice wheat zone , otherwise Zero;	0.21	0.41	0	1
Dmw	dummy variable assuming value of One if farm is located at mixed wheat zone , otherwise Zero;	0.22	0.41	0	1
	Time Dummies				
dt_2	dummy variable assuming value of One if agriculture year is 2006-07, otherwise Zero;	0.33	0.471	0	1
dt_3	dummy variable assuming value of One if agriculture year is 2007-08, otherwise Zero;	0.33	0.471	0	1
	Climate variables-				
T_1	20 years moving average of mean temperature for first quarter months (April-June).	34.09	1.66	30.43	36.02
T_2	20 years moving average of mean temperature for second quarter months(July-Sep)	31.13	2.33	27.51	34.57
T_3	20 years moving average of mean temperature for third quarter months(Oct-Dec)	17.26	1.66	14.90	20.17
T_4	20 years moving average of mean temperature for fourth quarter months(Jan-March)	16.46	1.36	13.50	18.70
P_1	20 years moving average of mean precipitation for first quarter months (April-June).	35.24	12.23	18.63	68.89
P_2	20 years moving average of mean precipitation for second quarter months(July-Sep)	89.22	29.11	40.78	161.39
P_3	20 years moving average of mean precipitation for third quarter months(Oct-Dec)	16.68	8.75	8.10	50.22
P_4	20 years moving average of mean precipitation for fourth quarter months(Jan-March)	9.77	5.98	3.32	27.50
	Variables for inefficiency determinants-				
age	age of the head of household in years;	43.31	14.14	14.00	80.00
edu	education of the head of the household in years of schooling;	6.44	4.66	0.00	16.00
farmsize	total area of farm in acres.	39.38	56.02	1.00	581.00
dtenant	dummy variable assuming value of One if the farm is rented in, otherwise Zero;	0.03	0.18	0.00	1.00
DVt1	Deviation of first quarter average temperature from 20 year moving average of these months (Celsius degree).	-1.00	0.43	-2.42	-0.20
DVt2	Deviation of second quarter average temperature from 20 year moving average of these months (Celsius degree).	-2.01	1.71	-5.90	-0.18
DVt3	Deviation of third quarter average temperature from 20 year moving average of these months (Celsius degree).	-0.92	1.45	-4.63	0.69
DVt4	Deviation of fourth quarter average temperature from 20 year moving average of these months (Celsius degree).	0.72	1.96	-2.46	3.48
DVP1	Deviation of first quarter average rainfall from 20 year moving average of these months (mm).	23.51	23.54	-43.42	75.24
DVP2	Deviation of second quarter average rainfall from 20 year moving average of these months (mm).	23.52	26.09	-24.76	96.74
DVP3	Deviation of third quarter average rainfall from 20 year moving average of these months (mm).	-0.29	7.56	-21.00	26.29
DVP4	Deviation of fourth quarter average rainfall from 20 year moving average of these months (mm).	4.74	11.76	-9.86	45.01

References

Adams, R.M., McCarl, B.A. Dudek, D.J. & Glyer, J.D. (1988). Implications of global climate change for Western agriculture. *Western Journal of Agricultural Economics*, 13(2), 348-356.

Ahmad, M. (2003). Agricultural productivity, efficiency, and rural poverty in irrigated Pakistan: A stochastic production frontier analysis. *The Pakistan Development Review.* 42(3),219 -248.

Ahmad, M., Chaudhry, G., Iqbal, M., & Khan, D.A. (2002). Wheat productivity, efficiency, and sustainability: A stochastic production frontier analysis. *The Pakistan Development Review*, 41(4), 643 -663.

Ahmed, M., Nawaz, M. Iqbal, M., & Javed, S.A. (2014). Analyzing the impact of climate change on rice productivity in Pakistan. *Climate Change Working Papers Series,* No.2. [Retrieved from].

Ali, F., Parikh, A., & Shah, M.K. (1996). Measurement of Economic Efficiency Using the Behavioral and Stochastic Cost Frontier Approach. *Journal of Policy Modeling*, 18(3), 271-287. doi. 10.1016/0161-8938(95)00142-5

Ali, F., Parikh, A., & Shah, M. (1994). Measurement of profit efficiency using behavioral and stochastic frontier approaches. *Applied Economics,* 26(2),181-188. doi. 10.1080/00036849400000074

Ali, M., & Flinn, J.C. (1989). Profit efficiency among Basmati rice producers in Pakistan Punjab. *American Journal of Agriculture Economics*, 71(2), 303 -310. doi. 10.2307/1241587

Amiraslany, A. (2010). The impact of climate change on Canadian agriculture: A Ricardian approach. PhD Thesis Submit to the Department of Bioresource Policy, Business and Economics. *University of Saskatchewan Saskatoon.*

Battese, G.E. (1997). A note on the estimation of Cobb-Douglas production functions when some explanatory variables have zero values. *Journal of Agricultural Economics*, 48(1-3), 250 -252. doi. 10.1111/j.1477-9552.1997.tb01149.x

Battese, G.E., & Coelli, T.J. (1995). A model for technical inefficiency effect in stochastic frontier production functions for panel data. *Empirical Economics,* 20(2), 325-332. doi. 10.1007/BF01205442

Battese, G.E., Malik, S.J., & Broca, S. (1993). Production functions for wheat farmers in selected districts of Pakistan: An application of a stochastic frontier production function with time-varying inefficiency effects. *The Pakistan Development Review,* 32(3), 233-268.

Battese, G.E., & Broca, S.S. (1997). Functional forms of stochastic frontier production functions and models for technical inefficiency effects: A comparative study for wheat farmers in Pakistan. *Journal of Productivity Analysis,* 8(4), 395-414. doi. 10.1023/A:1007736025686

Bauer, P.W. (1990). Recent developments in the econometric estimation of frontiers. *Journal of Econometrics*, 46(1), 39- 56. doi. 10.1016/0304-4076(90)90046-V

Berger, A.N., Hancock, D., & Humphrey, D.B. (1993). Bank efficiency derived from the profit function. *Journal of Banking and Finance*, 17(2), 317-347. doi. 10.1016/0378-4266(93)90035-C

Bravo-Ureta, B.E., Solís, D. .López, V.H.M., Maripani, J.F., Thiam, A., & Rivas, T. (2007). Technical efficiency in farming: A meta-regression analysis. *Journal of productivity Analysis*, 27(1), 57-72. doi. 10.1007/s11123-006-0025-3

Bravo-Ureta, B.E., & Pinherio, A.E., (1993). Efficiency analysis of developing country agriculture: A review of the frontier function literature. *Agriculture Resource Economic Review,* 22(1), 88-101. doi. 10.1017/S1068280500000320

Cabas, J., Weersink, A., & Olale, E. (2010). Crop yield response to economic, site and climatic variables. *Climatic Change,* 101(3-4), 599- 616. doi. 10.1007/s10584-009-9754-4

Cicerone, R.J., & Shetter, J.D. (1981). Sources of atmospheric methane: Measurements in rice paddies and a discussion. *Journal of Geophysical Research*, 86(C8), 7203-7209. doi. 10.1029/JC086iC08p07203

Coelli, T.J. (1995). Recent developments in frontier modelling and efficiency measurement. *Australian Journal of Agricultural Economics,* 39(3), 219 -245. doi. 10.1111/j.1467-8489.1995.tb00552.x

Coelli, T.J. (1993). Finite sample properties of stochastic frontier estimators and associated test statistics. *Working Papers in Econometrics and Applied Statistics,* No.70, Department of Econometrics, University of New England, Armidale. [Retrieved from].

Cornwell, C., Schmidt, P., & Sickles, R.C. (1990) Production Frontiers with Cross-Sectional and Time-Series Variation in Efficiency Levels. *Journal of Econometrics*, 46(1-2), 185-200. doi. 10.1016/0304-4076(90)90054-W

Crosson, P. (1997). Impacts of Climate Change on Agriculture. Climate Issues Brief. *Journal Resources and Economics.* No.4.

Demir, N. & Mahmud, S.F. (2002). Agro-climatic conditions and regional technical inefficiencies in agriculture. *Canadian Journal of Agricultural Economics,* 50(3), 269 -280. doi. 10.1111/j.1744-7976.2002.tb00337.x

Diewert, W.E. (1993). *The Measurement of Productivity: A Survey.* Swan Consultants, Canberra.

Eaton, J., & Panagariya, A. (1982). Growth and welfare in a small, open economy. *Economica,* 49(196), 409-419. doi. 10.2307/2552961

Eriksen, S., O'Brien, K., & Rosentrater, L. (2008). Climate change in Eastern and Southern Africa: Impacts, vulnerability and adaptation. Department of Sociology and Human Geography, University of Olso. [Retrieved from].

Finger, R., & Schmidt, S. (2007). Modelling Agriculture Production Risk and the Adaptation to Climate Change. Paper Presented for Presentation at the 101 EAAE Management of Climate Risk in Agriculture. *Berlin. MPRA Paper,* No. 394. [Retrieved from].
Gbetibouo, G.A., & Hassan, R.M. (2005). Measuring the economic impact of climate change on major South African field crops: A Ricardian approach. *Global and Planetary Change*, 47(2), 143-152. doi. 10.1016/j.gloplacha.2004.10.009
Greene, W.H. (1995). Frontier production functions. *In* H. Pesaran & P. Schmidt (eds) *Handbook of Applied Econometrics*, Vol. II- Microeconomics. London: Basil Blackwell.
Hanif, U., Syed, S.H., Ahmad, R., Malik, K.A., & Nasir, M. (2010). Economic impact of climate change on the agricultural sector of Punjab. *The Pakistan Development Review*, 49(4), 771-798.
Hughes, N., Lawson, K., Davidson, A., Jackson, T., & Sheng, Y. (2011). Productivity pathways: Climate-adjusted production frontiers for the Australian broadacre cropping industry. In *2011 Conference (55th), February 8-11, 2011, Melbourne, Australia* (No.100563). Australian Agricultural and Resource Economics Society. [Retrieved from].
IPCC, (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the IPCC. *Stocker TF, et al., editors. IPCC.* [Retrieved from].
Iqbal, M.M., Hussain, S.S., Goheer, M.A., Sultana, H., Salik, K.M., Mudasser, M., & Khan, A.M. (2008). Climate change and wheat production in Pakistan: Calibration, validation and application of CERES wheat model. *GCISC Research Report 14*, Global Change Impact Studies Centre, Islamabad, Pakistan. [Retrieved from].
Javed, M.I., Adil, S.A., Hassan, S., & Al, A. (2009). An Efficiency Analysis of Punjab's Cotton-Wheat System. [Retrieved from].
Javed, M.I., Khurshid, W., Adil, A.S., Hassan, I., Nadeem, N., Ali, A., & Raza, M.A. (2011). Analysis of technical and scale efficiency of smallholder farms of rice-wheat system in Punjab, Pakistan. *Journal of Agricultural Research,* 49(1), 125-137.
Kumbhakar, S.C. (2001). Estimation of profit functions when profit is not maximum. *American Journal of Agriculture Economics,* 83(1), 1-19. doi. 10.1111/0002-9092.00133
Kumbhakar, S.C., & Lovell, C.K. (2003). *Stochastic Frontier Analysis*. Cambridge University Press.
Lee, J., Nadolnyak, D.A., & Hartarska, V.M. (2012). Impact of climate change on agricultural production in Asian countries: Evidence from panel study. Annual Meeting, February 4-7, 2012, Birmingham, Alabama 119808. Southern Agricultural Economics Association. [Retrieved from].
Leichenko, R., & O'Brien, K. (2006). Is it Appropriate to Identify Winners and Losers? *in* R. Leichenko & K. O'Brain, *Fairness in Adaptation to Climate Change*, (pp.97-114), MIT Press.
Lobell, D.B., Cahill, K.N., & Field, C.B. (2007). Historical effects of temperature and precipitation on California crop yields. *Climatic Change*, 81(2), 187-203. doi. 10.1007/s10584-006-9141-3
Lovell, C.A.K. (1993). Production frontiers and productive efficiency. *in* H.O. Fried & S.S. Schmidt (Eds.) *The Measurement of Productive Efficiency: Techniques and Applications*, (pp.3-67), Oxford U.K.
Molua, E., & Lambi, C.M. (2007). The economic impact of climate change on agriculture in Cameroon. World Bank Development Research Group, Sustainable Rural and Urban Development Team. *Policy Res. Work*, No.4364. [Retrieved from].
Nasim, S., Dinar, A., & Helfand, S. (2014). Allocative inefficiency and farm-level constraints in irrigated agriculture in Pakistan. *Intl Food Policy Res Inst.*15. [Retrieved from].
Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T. Zhu, T. & Lee, D. (2009). Climate change: Impact on agriculture and costs of adaptation. *Intl Food Policy Res Inst. 21.* [Retrieved from].
Nganga, S.K., Kungu, J., & Ridder, N.D. (2010). Profit efficiency among Kenyan smallholder's milk producers: A case study of Meru-South district Kenya. *African Journal of Agricultural Research* 5(4), 332-337.
O'Brien, K.L., & Leichenko, R.M. (2003). Winners and losers in the context of global change. *Annals of the Association of American Geographers*, 93(1), 89-103. doi. 10.1111/1467-8306.93107
Parry, M.L., Rosenzweig, C., Iglesias, A., Livermore, M., & Fischer, G. (2004). Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change*, 14(1), 53- 67. doi. 10.1016/j.gloenvcha.2003.10.008
Pereda, P., & Alves, D.C. (2012). Climate and weather impacts on agriculture: The case of Brazil. *Unpublished paper*. [Retrieved from].
Rahman, S. (2003). Profit efficiency among Bangladeshi rice farmers. 25th International Conference of Agricultural Economists (IAAE), 16-22 August, South Africa. [Retrieved from].
Ramanathan, V., Li, F., Ramana, M.V., Praveen, P.S., Kim, D., Corrigan, C.E., & Yoo, S.C. (2007). Atmospheric brown clouds: Hemispherical and regional variations in long-range transport, absorption, and radiative forcing. *Journal of Geophysical Research: Atmospheres* (1984–2012), 112(D22), 27. doi. 10.1029/2006JD008124
Rehan, R.., & Nehdi, M. (2005). Carbon dioxide emissions and climate change: Policy implications for the cement industry. *Environmental Science and Policy*, 8(2), 105-114. doi. 10.1016/j.envsci.2004.12.006
Rios, A.R., & Shively, G.E. (2005). Farm size and nonparametric efficiency measurements for coffee farms in Vietnam. Selected Paper Prepared for Presentation at the American Agricultural

Economics Association Annual Meeting, Providence, Rhode Island and Purdue University ARP manuscript, No.17671. [Retrieved from].
Schipper, F.L.E. (2004). Exploring Adaption to Climate Change, A Development Prospective. PhD Thesis Submitted to University of East Anglia.
Schmidt, P. (1976). On the statistical estimation of parametric frontier production functions. *Review of Economics and Statistics,* 58(2), 238 -239. doi. 10.2307/1924032
Schmidt, P. (1985-86). Frontier production functions. *Econometric Reviews*. 4(2), 289-328. doi. 10.1080/07474938608800089
Schmidt, P., & Sickles, R.C. (1984). Production Frontiers and Panel Data. *Journal of Business and Economic Statistics*, 2(4), 367-374.
Steffen, W., Sanderson, A., Tyson, P.D., Jaeger, J., Matson, P.A., Moore, B., Oldfield, F., Richardson, K., Schnellnhuber, H.J., Turner, B.L., & Wasson, R.J. (2004). *Global Change and the Earth System: A Planet under Pressure*. Berlin: Springer-Verlag. 336.
UNEP, (2003). GEO Year Book 2003. Nairobi: UNEP.
USAID, (2009). Office of Foreign Disaster Assistance (OFDA).Annual Report for Fiscal year 2009. [Retrieved from].
Wadud, M.A. (2003). Technical, allocative, and economic efficiency of farms in Bangladesh: A stochastic frontier and DEA approach. *The Journal of Developing Areas*, 37(1), 109-126. doi. 10.1353/jda.2004.0019
Walsh, C.M. (1901*). The Measurement of General Exchange-Value* (Vol. 25). Macmillan.
Warraich, M., & Mohsin, C.H. (2005). Orchard Contracting System, Is There a Possibility for Shift? Presented in Workshop on Citrus Research, Development and Extension in Pakistan and Australia: Islamabad, Pakistan.
White, M.R. (1985). Characterization of Information Requirements for the Studies of CO_2 Effects: Water Resources, Agriculture, Fishries, Forests and Human Health. Unite State Department of Energy ER-0236.

Copyrights
Copyright for this article is retained by the author(s), with first publication rights granted to the journal. This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by-nc/4.0).